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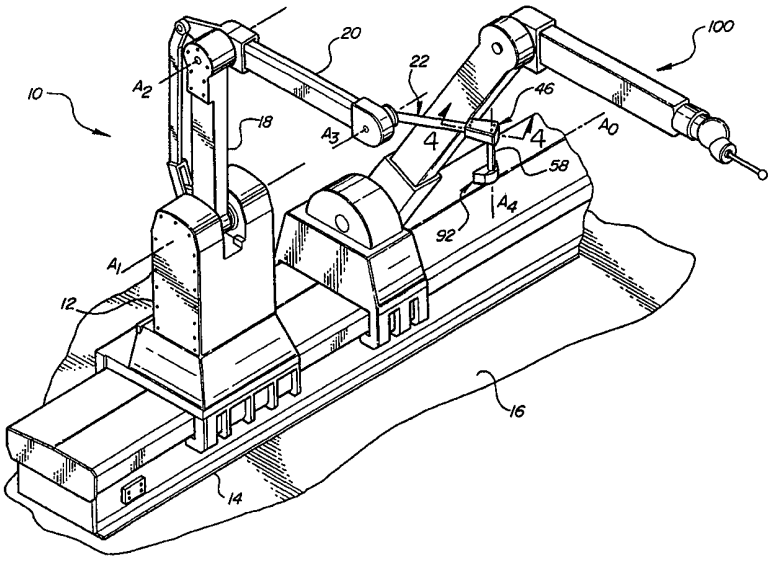

(57) Abstract

A robot assembly (10) for opening and holding an automotive door including a base (12) movably mounted to a platform (14). An inner robot arm (18) is pivotally mounted to the base. An outer robot arm (20) is pivotally mounted to the inner arm (18). A tool arm (22) includes a shaft (58) presenting a second tool arm axis (A4) for rotation about the second tool arm axis (A4). A sphere (90), presenting first, second and third sphere axes (A5, A6, A7), is mounted to the distal end of the shaft (58) for rotatably supporting a magnet tool (118). A pin (104) extends from the sphere (90) for preventing the rotation of the tool (118) about the first sphere axis (A5) which is parallel to the second tool arm axis (A4). The robots arms (18, 20) maneuver the tool (118) such that the tool (118) engages and opens the door.

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AUTOMOTIVE DOOR OPENING ROBOT ASSEMBLY

BACKGROUND OF THE INVENTION

1. Field of the Invention

The subject invention relates to robot assembly for opening and holding an automotive door.

2. Description of the Prior Art

The typical procedure for robotically painting the interior of an automotive vehicle frame involves robotically moving a door of the vehicle from a closed position to an open position. The door is then robotically held in the open position while the interior is robotically painted. Having painted the interior, the door is robotically returned to the closed position.

Various robotic devices have been proposed by the prior art for opening and holding a door of an automotive vehicle for the purpose of painting the interior of the vehicle frame. Typical of these devices is U.S. patent 4,342,536 to Akeel. However, these types of devices require a separate fixture to be removably mounted to the door in order for the robot device to grasp and maneuver the door. Accordingly, these devices require additional process time to install and remove the fixture.

Other devices, such as U.S. patent 5,286,160 to Akeel, do not require a separate fixture to be removably mounted to the vehicle. However, these types of devices require a separate robotic apparatus for moving the door between the closed and open positions, and a separate robotic apparatus for holding the door in the open position. In addition, these devices require end effector servomechanisms in addition to the required robot arm servomechanisms. Thus, these devices are relatively expensive, as well as, require additional time and cost to program.

Thus, there is a need for a robot assembly for opening and holding an automotive door which is relatively inexpensive and reduces the time and cost associated with programming the servomechanism.

SUMMARY OF THE INVENTION AND ADVANTAGES

A robot assembly for opening and holding an automotive door comprising a base movably mounted to a platform. An inner robot arm is pivotally mounted to a base for movement about an inner arm axis. An outer robot arm is pivotally mounted to the inner arm for movement about an outer arm axis. A tool arm is pivotally mounted to the outer robot arm for movement about a first tool arm axis. The tool arm includes a support housing and a shaft presenting a second tool arm axis. The shaft is rotatably supported by said support housing for rotation about the second tool arm axis. A tool support member and the shaft are interconnected by a sphere disposed in a socket for rotatably supporting the tool support member.

The assembly eliminates the need for servomechanisms to control the positioning of the tool support member or end effector relative to the tool arm.

Accordingly, the subject invention provides a robot assembly for opening and holding a door which is relatively inexpensive and eliminates the time and cost associated with programming end effector servomechanisms.

BRIEF DESCRIPTION OF THE DRAWINGS

Other advantages of the subject invention will be readily appreciated as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings wherein:

Figure 1 is a perspective view of the subject robot assembly in relationship to a painting robot;

Figure 2 is an elevation view of the subject robot assembly illustrating the orientation of the tool arm relative to movement of the robot arms;

Figure 3 is a sectional view taken along the line 3 - 3 of Figure 2;

Figure 4 is a partial sectional view taken along the line 4 - 4 of Figure 1;

Figure 5 is a top view of Figure 4 with the cover partially broken away showing the magnet tool rotated approximately 70° relative to the home position, and showing the magnet tool in the home position in phantom;

Figure 6 is view taken along the line 6 - 6 of Figure 4;

Figure 7 a rear view of Figure 6 with the rear plate removed; and

Figure 8 is an exploded view tool support member and magnet tool.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to the Figures, wherein like numerals indicate like or corresponding parts throughout the several views, a robot assembly for opening and holding an automotive door during a painting operation is generally shown at **10**. The assembly **10** includes a base **12**. The base **12** is slidably mounted to a platform or rail **14** presenting a rail axis A_0 for rectilinear movement relative to the rail axis A_0. The rail **14** is secured to a floor **16** or the like. The base **12** is moved in a manner well known in the art. Alternatively, as can be appreciated by one skilled in the art, a base, presenting a generally vertical base axis, could be rotatably mounted to a platform for rotation about the base axis. Consistent with the preferred embodiment, the base in this alternative embodiment is moved in a manner well known in the art. An inner robot arm **18** is pivotally mounted to the base **12** for movement about an inner robot arm axis A_1. An outer robot arm **20** is pivotally mounted to the inner robot arm **18** for movement about an outer robot arm axis A_2. The robot arms **18** and **20** are articulated in a manner well known in the art.

A tool arm, generally indicated at **22**, is pivotally mounted to the outer robot arm **20** for movement about a first tool arm axis A_3. As illustrated in Figure 2, the movement of the tool arm **22** about the first tool arm axis A_3 is controlled in a manner well known in the art, and is such that the orientation of the tool arm **22** with respect to the floor **16** is held constant for any articulation of the robot arms **18** and **20**.

The tool arm **22** includes a clutch plate **24** having a front face **26** and a rear face **28** opposite the front face **26**. The clutch plate **24** is detachably connected to the outer robot arm **20** by multiple nylon screws **30** for disconnecting the tool arm **22** from the outer robot arm **20** in the event the tool arm **22** is subjected to excessive loading. As can be appreciated, the material and size of the screws **30** can vary depending on the load at which the tool arm **22** is desired to breakaway from the outer robot arm **20**.

The assembly **10** further includes a tool arm sensing means for sensing when the tool arm **22** is disconnected from the outer robot arm **20**. The sensing means is of a type well known in the art, and includes a female electrical connector **34** mounted to the clutch plate **24** and a male electrical connector **36** mounted to the outer robot arm **20**. The female connector **36** includes electrical wiring **38** routed through the robot arms **18** and **20**. Alternatively, the orientation of the connectors **34** and **36** can be reversed.

A hollow support beam **44** extends from the rear face **28** of the clutch plate **24** at an acute angle relative to the rear face **28** of the clutch plate **24** and is substantially parallel to the floor **16**. An L-shaped support housing, generally indicated at **46**, is connected to the support beam **44**. The support housing **46** includes a guide tube **48** having first **50** and second **52** ends. The guide tube **48** is directed at approximately a 90° angle relative to the support beam **44**. As can be appreciated, the optimal orientation of the support beam **44** and/or of the guide tube **48** can vary depending on the given robotic operation to be performed. A frictionless sleeve **54** having a lip **56** is inserted in the tube **48**, wherein the lip **56** rests on the first end **50** of the tube **48**. A

shaft **58** presenting a second tool arm axis A_4 is disposed in the tube **48** for rotation about the second tool arm axis A_4. First **60** and second **62** ends of the shaft **58** extend outwardly from the first **50** and second **52** ends of the tube **48**, respectively. The diameter of the portion of the shaft **58** extending outwardly from the second end **52** of the tube **48** is larger than the opening in the tube **48** preventing the shaft **58** from moving upward relative to the tube **48**.

A clevis **64** is bolted around a squared section **66** of the shaft **58**, wherein the clevis **64** rests on the lip **56** of the sleeve **54**. A post **68** is press fitted into the support housing **46** adjacent to the support beam **44**. A biasing spring **70** is operatively connected to the clevis **64** and the post **68** for placing shaft **58** in a home position with respect to the second tool arm axis A_4.

A circular proximity tab **72** extends upwardly from the first end **60** of the shaft **58** tracing approximately 120° of the circumference of the shaft **58**. A proximity sensor **74** is positioned by a bracket **76** adjacent to the proximity tab **72** for detecting the presence of the proximity tab **72** for providing a signal when the shaft **58** has rotated a specified angular rotation with respect to the home position. The proximity sensor **74** is of a type well known in the art. The proximity tab **72** is located on the shaft **58** such that the leading edge of the proximity tab **72** is directly aligned with the proximity sensor **74** when the shaft is rotated approximately 15° relative to the home position. The proximity sensor **74** and the female connector **34** are interconnected by electrical wiring **78** routed through the support housing **46** and the support beam **44**. As can be appreciated, the placement of the proximity tab **72** relative to the shaft **58** can vary depending on the amount of rotation of the shaft **58** at which the proximity sensor **74** is intended to detect the presence of the proximity tab **72**.

A pair of stop rods **80** are press fitted in the support housing **46** for engaging the clevis **64** for preventing the shaft **58** from rotating beyond a maximum angular rotation relative to the home position (Figure 5). In the preferred embodiment, the placement of the stop rods **80** is such that shaft **58**

is prevented from rotating beyond plus or minus approximately 80° relative to the home position. As can be appreciated, the placement of the stop rods **80** can be varied so as to vary the maximum angular rotation relative to the home position.

The tool arm **22** further includes a removable cover **82** screwed to the support housing **46** for protecting the components housed within the support housing **42** and for providing access for servicing such components.

The shaft **58** is hollow adjacent to the second end **62** of the shaft **58** and presents an opening **84** therein which extends through the outer diameter of the shaft **58**. A stem **86** extends from the second end **62** of the shaft **58** and is secured to the shaft **58** by a pin **88** press fitted in the opening **84** in the shaft **58**. A sphere **90** is pressed onto the distal end of the stem **86**. Alternatively, the shaft **58** and the stem **86** can machined from a single piece of stock.

The assembly **10** further includes a tool support member, generally indicated at **92**, rotatably supported by the sphere **90**. The tool support member **92** includes a front plate **94** bolted to a rear plate **96**. A front face **97** of the front plate **94** is directed toward the robot arm **18** and **20**, and is generally parallel to the robot and first tool arm axes A_1, A_2 and A_3, respectively, when the shaft **58** is in the home position. The inner surfaces of the plates **94** and **96** form a socket **98** and an opening **100** extending from the socket **98**. The stem **86** extends through the opening **100** and the sphere **90** is disposed in the socket **98**. A cavity **102** extends from opposite sides of the socket **98**. A pin **104** extends from opposite sides of the sphere **90**. The pin **104** is disposed in the cavity **102** for preventing the rotation of the tool support member **92** about a first sphere axis A_5 which passes through the center of the sphere **90** parallel to the second tool arm axis A_4.

The tool support member **92** further includes a collar **106** adjacent to the second end **62** of the shaft **58**. As best shown in Figure 7, clearance is provided between the stem **86** and the opening **100**, between the pin **104** and the cavity **102**, and between the collar **106** and the second end **62** of the shaft

58 for allowing the tool support member **92** to rotate about the sphere **90** in any direction except for, as discussed above, about the first sphere axis A_5. The clearance gap between the collar **106** and the second end **62** of the shaft **58** defines the range in which the tool support member **92** is allowed to rotate about the sphere **90**. In other words, the tool support member **92** is prevented from rotating about the sphere **90** beyond the point at which the collar **106** engages the shaft **58**. As can be appreciated, the clearance gap between the collar **106** and the shaft **58** can be varied to alter the range in which the tool support member **92** is allowed to rotate about the sphere **90**.

As best shown in Figures 7 and 8, the tool support member **92** further includes a pair of slots **108** on opposite sides of the socket **98** and extending substantially perpendicular to and from the cavity **102**. A biasing spring **110** is disposed in each the slots **108** and engages the pin **104**. The biasing springs **110** place the tool support member **92** in a normal position with respect to a second sphere axis A_6 which passes through the center of the sphere **90** perpendicular to both the pin **104** and the stem **86** (Figure 4). In addition, the tool support member **92** has a defined normal position with respect to a third sphere axis A_7 which passes through the center of the sphere **90** parallel to the pin **104** (Figures 4 and 7). In the preferred embodiment, the clearance gap between the collar **106** and the second end **62** of the shaft **58** is such that the range of rotation of the tool support member **92** about each of the second A_6 and third A_7 sphere axes is plus or minus 2.5° relative to the normal positions of the tool support member **92**.

The tool support member **92** further includes a sealing means for sealing the opening **100** and socket **98** (Figure 7). The sealing means includes a washer **112** and a seal **114** disposed within the collar **106** and around the stem **86**, wherein the seal **114** is placed above and adjacent to the washer **112**. A spring **116** is disposed in the seal **114** and around the stem **86** for maintaining a force on the washer **112** when the tool support member **92** rotates about the sphere **90**. As best shown in Figure 8, a magnet tool,

generally indicated at **118**, is supported by the tool support member **92** for opening and holding an automotive door during a given painting operation. The tool **118** includes a plurality of magnets **120** and a plurality of low carbon steel flux bars **122** disposed in a recess **124** on the front face **97** of the front plate **94**. The magnets **120** and flux bars **122** are arranged in alternating fashion, whereby each magnet **120** is positioned between two flux bars **122**. Additionally, the polarity of the magnets **120** is arranged in a SNNSSN manner. A magnetic cover **126** having a specified thickness is screwed to the front plate **94** so as to cover the recess **124**. As can be appreciated, the thickness of the magnetic cover **126** can be varied in order to vary the magnetic holding power of the tool **118**.

In operation, the robot arms **18** and **20** are articulated so as to maneuver the tool **118** into an automotive vehicle (not shown) through a window opening of a door and into engagement with an inner panel of the door when the door is in a closed position. Note. Because the tool **118** directly engages the door panel, there is no need for a separate fixture to be removably mounted to the door in order for the tool **118** to take hold of the door. The magnetic attraction between the tool **118** and the panel forces the tool **118** to rotate about the second tool arm, second sphere and third sphere axes A_4, A_6 and A_7, respectively, such that the face of the cover **126** is generally in complete contact with the panel. The rotation of the tool **118** about the second sphere and third sphere axes A_6 and A_7, respectively, forces the spring **116** disposed in the seal **114** to elastically deform. In turn, the spring **116** forces the washer **112** to maintain the seal to the opening **100** of the tool support member **92**. Having engaged the tool **118** and panel, the base **12** and the robot arms **18** and **20** are then articulated so as to force the door to travel to an open position. As the door opens, the tool **118** is again forced to rotate about the second tool arm, second sphere and third sphere axes A_4, A_6 and A_7, respectively. The magnetic holding power of the tool **118** is sufficient to enable the door to placed in the open position without the tool **118**

being displaced relative to the panel. Having opened the door sufficiently to cause the tool **118** to rotate 15° about the second tool arm axis A_4, the proximity sensor **74** detects the presence of the proximity tab **72** and provides a signal that the door is present. Conversely, in the event that the tool breaks free from the panel, the biasing spring **70** connected to the clevis **64** forces the tool **118** to return to the home position. In turn, the proximity sensor **74** detects the absence of the proximity tab **72** and signals that door is absent.

Additionally, in the event that the tool arm **22** or tool **118** collides with an object such that an excessive force is transmitted to the screws **30**, the screws **30** will fail allowing the tool arm **22** to breakaway from the outer robot arm **20**. In turn, the electrical connectors **34** and **36** disconnect providing a signal that the tool arm **22** has broken free from the outer robot arm **20**.

Having moved the door to the open position, the tool **118** holds the door in the open position while a separate painting robot **100** (Figure 1) performs a painting operation within the vehicle. Having painted the interior of the vehicle, the robot arms **18** and **20** maneuver the tool **118** so as to return the door to the closed position. Having closed the door, the robot arms maneuver the tool **118** away from the panel causing the tool **118** to disengage the panel. Having disengaged the tool **118** and the panel, the biasing spring **70** connected to the clevis **64** forces the tool **118** to return to the home position. At the same time, the biasing springs **110** engaged with the pin **104** force the tool **118** to return to the normal position relative to the second sphere axis A_6. Note. It is necessary to place the tool **118** in the normal position relative to the second sphere axis A_6 prior to opening the door so that the range of motion of the tool **118** is adequate to accommodate the travel of the door. However, because the magnetic attraction between the tool **118** and the door forces the tool **118** to be properly position relative to the third sphere axis A_7 when the tool **118** engages the door, it is not necessary to place the tool **118** in the normal relative to the third sphere axis A_7 prior opening the door.

Finally, the robot arms **18** and **20** maneuver the tool **118** back through the window opening.

The invention has been described in an illustrative manner, and it is to be understood that the terminology which has been used is intended to be in the nature of words of description rather than of limitation.

Obviously, many modifications and variations of the present invention are possible in light of the above teachings. It is, therefore, to be understood that within the scope of the appended claims, wherein reference numerals are merely for convenience and are not to be in any way limiting, the invention may be practiced otherwise than as specifically described.

CLAIMS

What is claimed is:

1. A robot assembly **(10)** comprising:

a platform **(14)**;

a base **(12)** movably mounted to said platform;

an inner robot arm **(18)** pivotally mounted to said base **(12)** for movement about an inner arm axis (A_1);

an outer robot arm **(20)** pivotally mounted to said inner arm **(18)** for movement about an outer arm axis (A_2);

a tool arm **(22)** pivotally mounted to said outer robot arm **(20)** for movement about a first tool arm axis (A_3);

said tool arm **(22)** including a support housing **(46)** and a shaft **(58)** presenting a second tool arm axis (A_4), said shaft **(58)** being rotatably supported by said support housing **(46)** for rotation about said second tool arm axis (A_4);

a tool support member **(92)** mounted to said shaft **(58)**;

said assembly **(10)** characterized by a socket **(98)** and a sphere **(90)** disposed in said socket **(98)** interconnecting said shaft **(58)** and said tool support member **(92)** for rotatably supporting said tool support member **(92)**.

2. An assembly as set forth in claim 1 including a cavity **(102)** and a pin **(104)** disposed in said cavity **(102)** interconnecting said shaft **(58)** and said tool support member **(92)** for preventing the rotation of said tool support member **(92)** about said sphere **(90)** parallel to said second tool arm axis (A_4).

3. An assembly as set forth in claim 2 including a biasing spring **(110)** engaged with said pin **(104)** for placing said tool support member **(92)** in a normal position with respect to said pin **(104)**.

4. An assembly as set forth in claim 3 including a pair of said biasing springs **(110)**, said springs **(110)** being located on opposite sides of said sphere **(90)**.

5. An assembly as set forth in claim 3 including a sealing means **(112, 114, 116)** for sealing said socket **(98)**.

6. An assembly as set forth in claim 5 wherein said sealing means **(112, 114, 116)** includes a washer **(112)** above and adjacent to said socket **(98)** and a seal **(114)** above and adjacent to said washer **(112)**.

7. An assembly as set forth in claim 6 including a spring **(116)** disposed in said seal **(114)** for applying a force to said washer **(112)**.

8. An assembly as set forth in claim 7 wherein said cavity **(102)** extends from opposite sides of said socket **(98)** and said pin **(104)** extends from opposite sides of said sphere **(90)**.

9. An assembly as set forth in claim 8 wherein said tool support member **(92)** includes said socket **(98)** and said shaft **(58)** includes said sphere **(90)**.

10. An assembly as set forth in claim 9 including an opening extending from said socket **(98)**, said shaft **(58)** extending into said opening.

11. An assembly as set forth in claim 1 including a clevis mounted to said shaft **(58)** and a biasing spring operatively connected to said clevis and said support housing **(46)** for placing said tool support member **(92)** in a home position with respect to said second tool arm axis (A_4).

12. An assembly as set forth in claim 11 including a stop rod mounted to said support housing **(46)** for engaging said clevis for preventing said shaft **(58)** from rotating beyond a maximum angular rotation with respect to said home position.

13. An assembly as set forth in claim 1 including a proximity tab extending from said shaft **(58)** and a proximity sensor for detecting the presence of said tab for providing a signal when said tool support member **(92)** has rotated about said second tool arm axis (A_4) a specified angular rotation with respect to said home position.

14. An assembly as set forth in claim 1 wherein said tool arm **(22)** includes a clutch plate **(24)** detachably mounted to said outer robot arm **(20)** for disconnecting said tool arm **(22)** from said outer robot arm **(20)** when said tool arm **(22)** is subjected to excessive loading.

15. An assembly as set forth in claim 14 including multiple screws **(30)** for detachably mounting said clutch plate **(24)** to said outer robot arm **(20)**, whereby said screws **(30)** fail when said tool arm **(22)** is subjected to excessive loading.

16. An assembly as set forth in claim 14 including a tool arm sensing means **(34, 36)** for sensing when said tool arm **(22)** is disconnected from said outer robot arm **(20)**.

17. An assembly as set forth in claim 16 wherein said tool arm sensing means **(34, 36)** includes a male electrical connector **(34)** mounted to said clutch plate **(24)** and a female electrical connector **(36)** mounted to said outer robot arm **(20)**.

18. An assembly as set forth in claim 1 including a magnet tool **(118)** supported by said tool support member **(92)** for engaging and holding a workpiece.

19. An assembly as set forth in claim 18 wherein said tool **(118)** includes a plurality of magnets **(120)** and a plurality of flux bars **(122)**, whereby each of said magnets **(120)** is positioned between two of said flux bars **(122)**.

20. An assembly as set forth in claim 18 wherein said tool **(118)** includes a magnetic cover **(126)**.

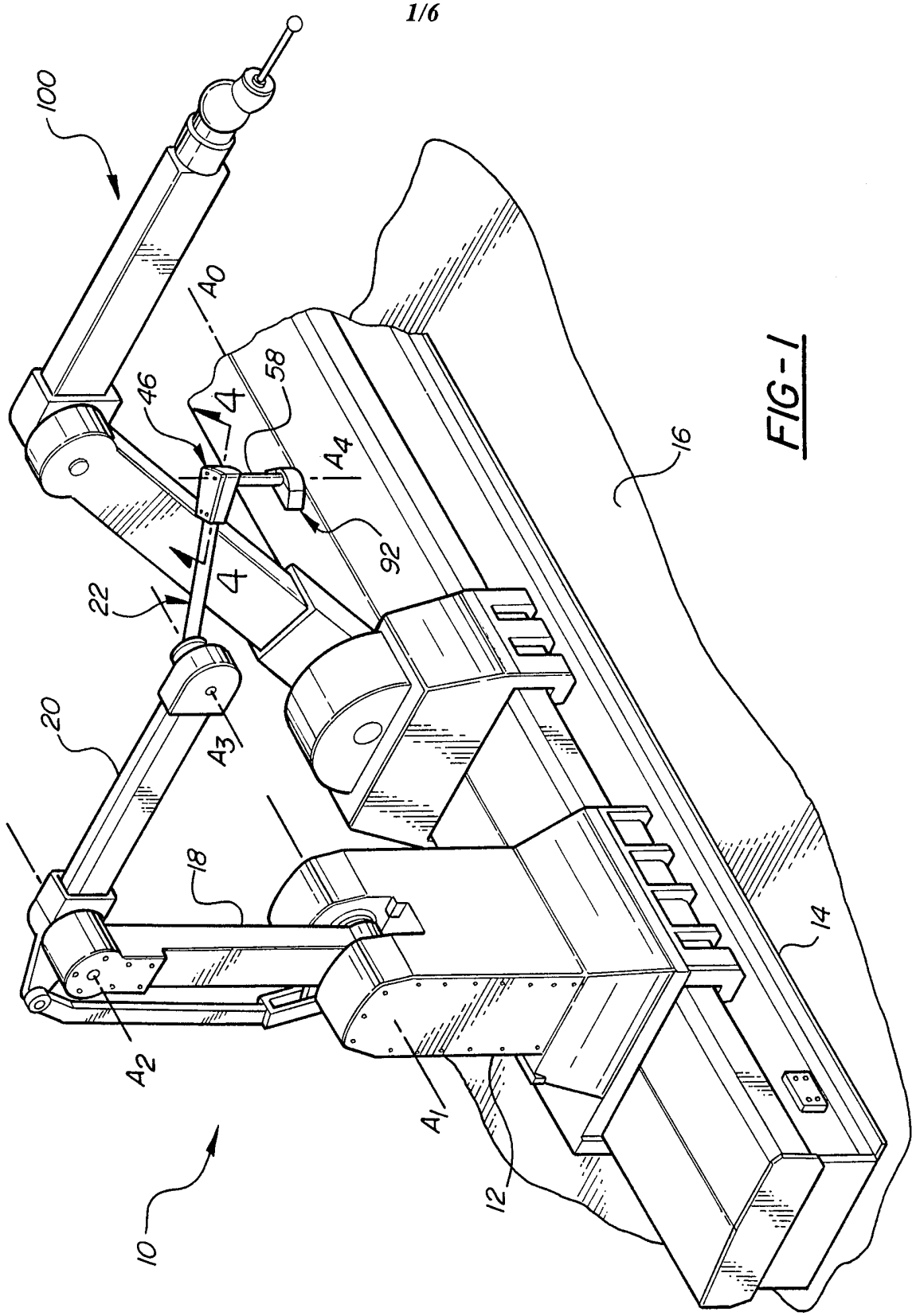


FIG-1

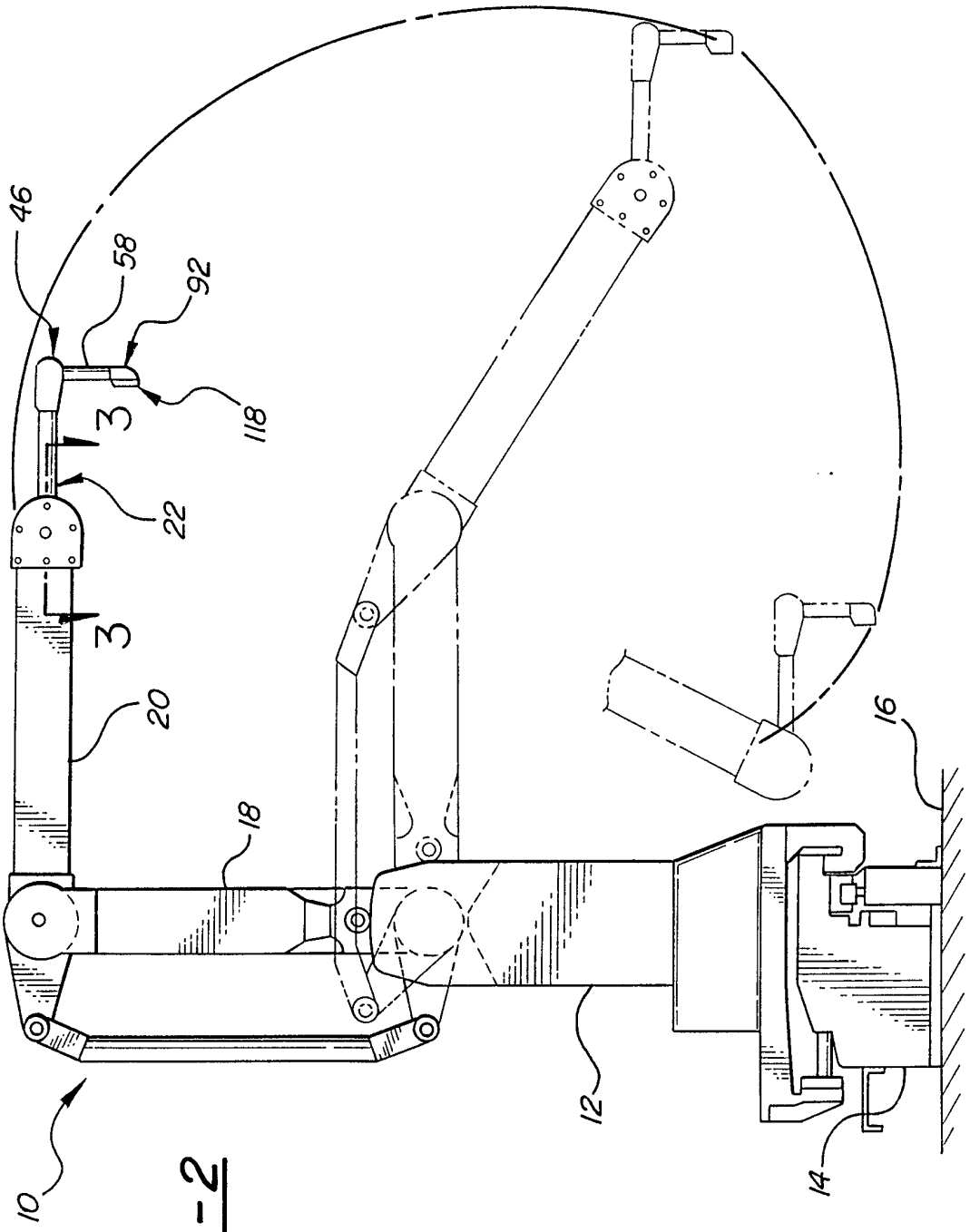
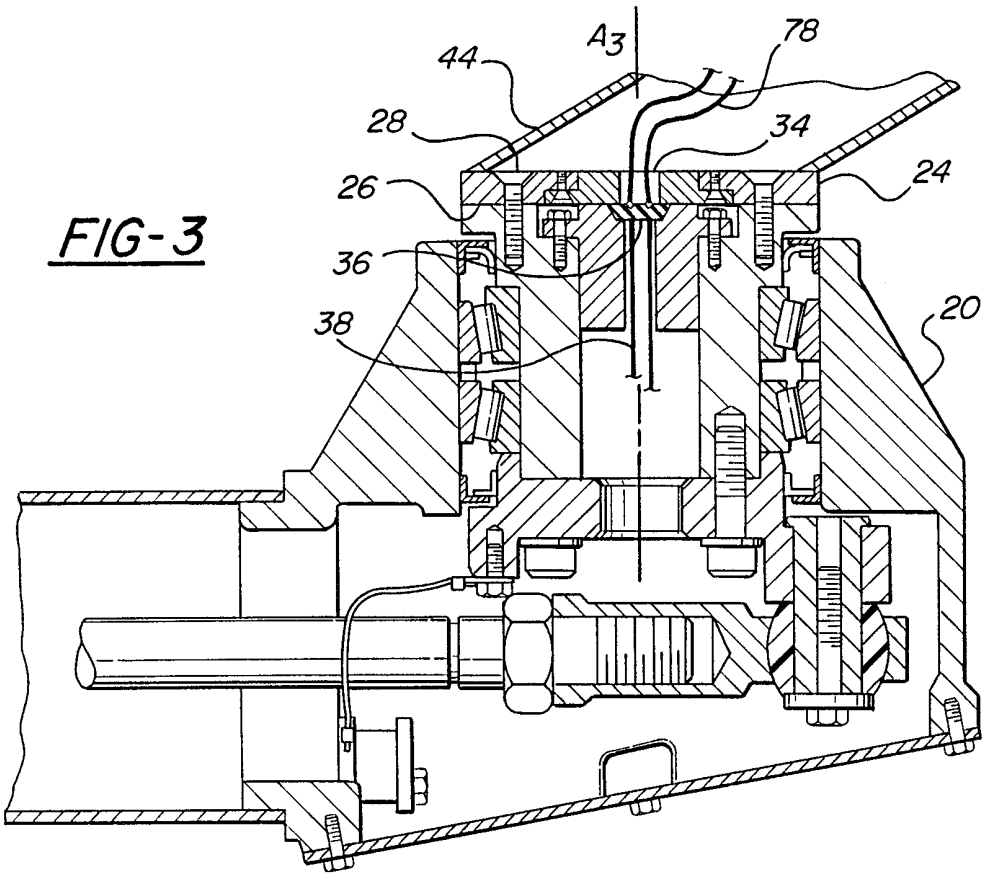


FIG-2

FIG-3


A3
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26
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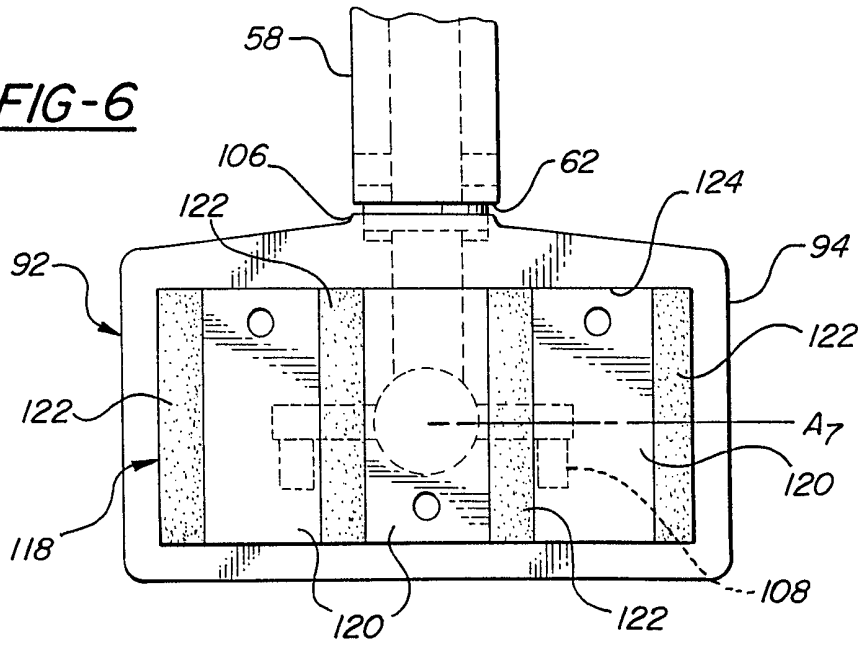
20

FIG-6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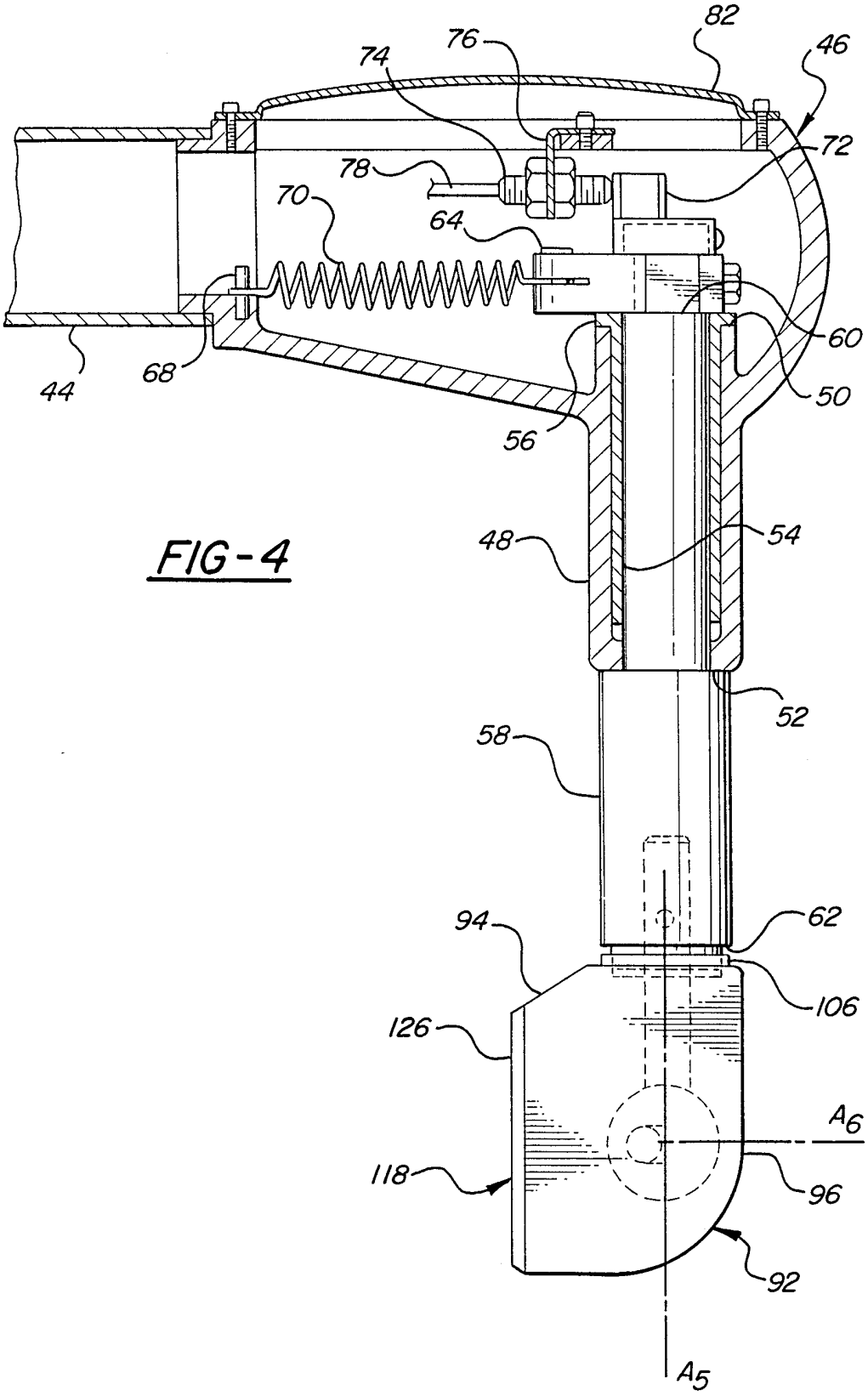
122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A_6
118
96
92
A_5

FIG-4

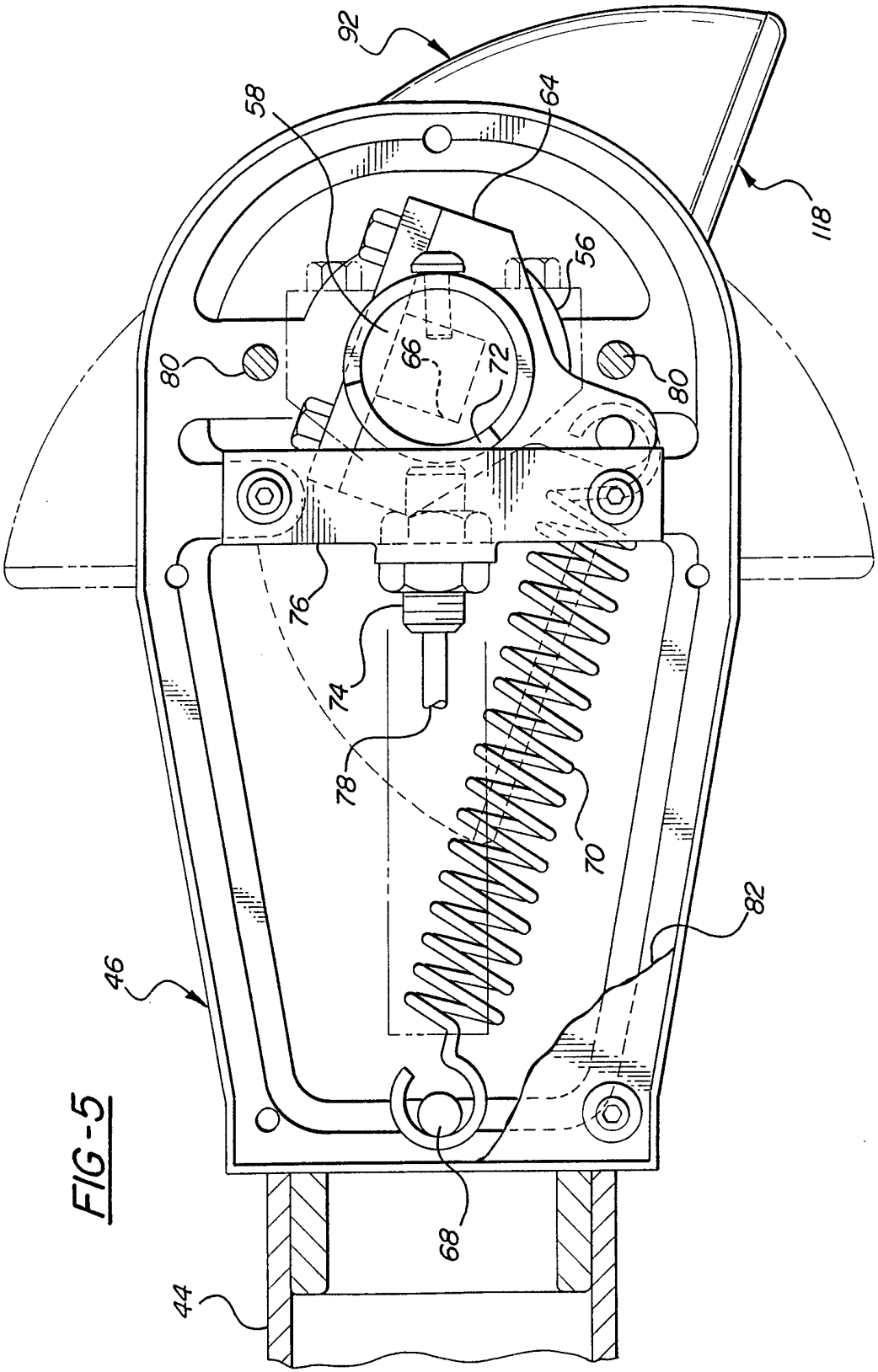
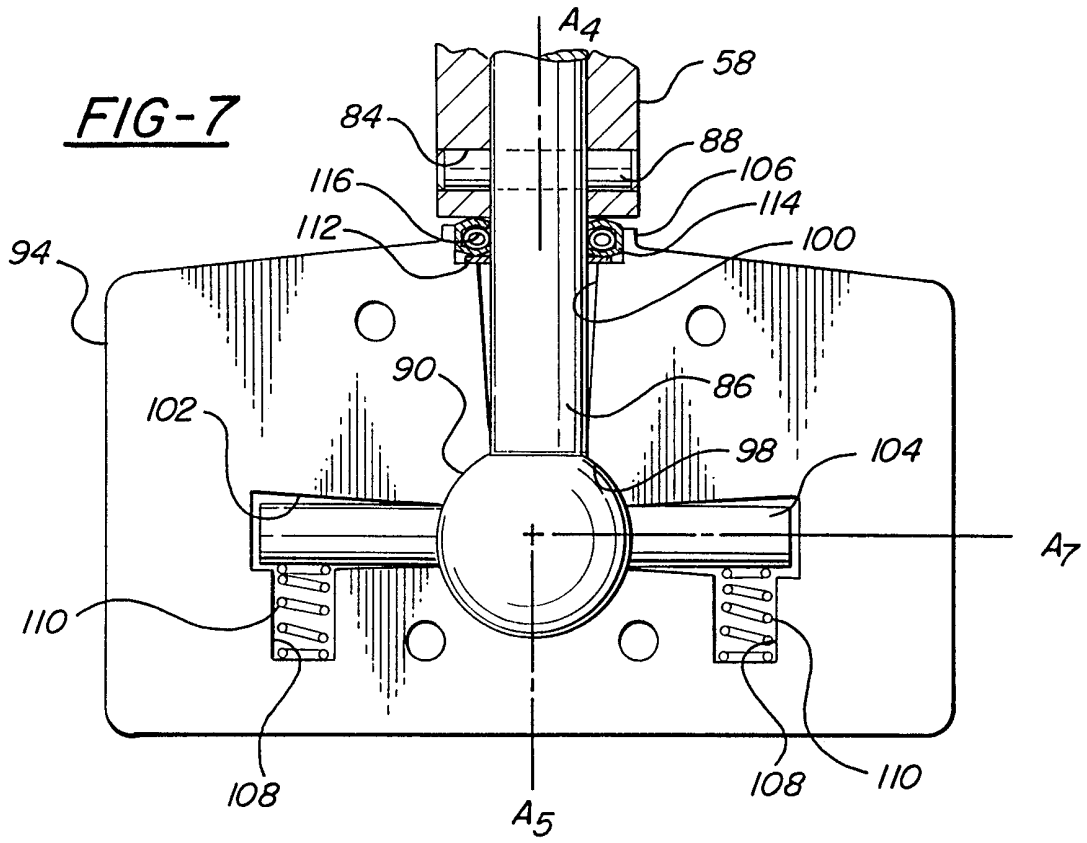


FIG-5

FIG-7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A7
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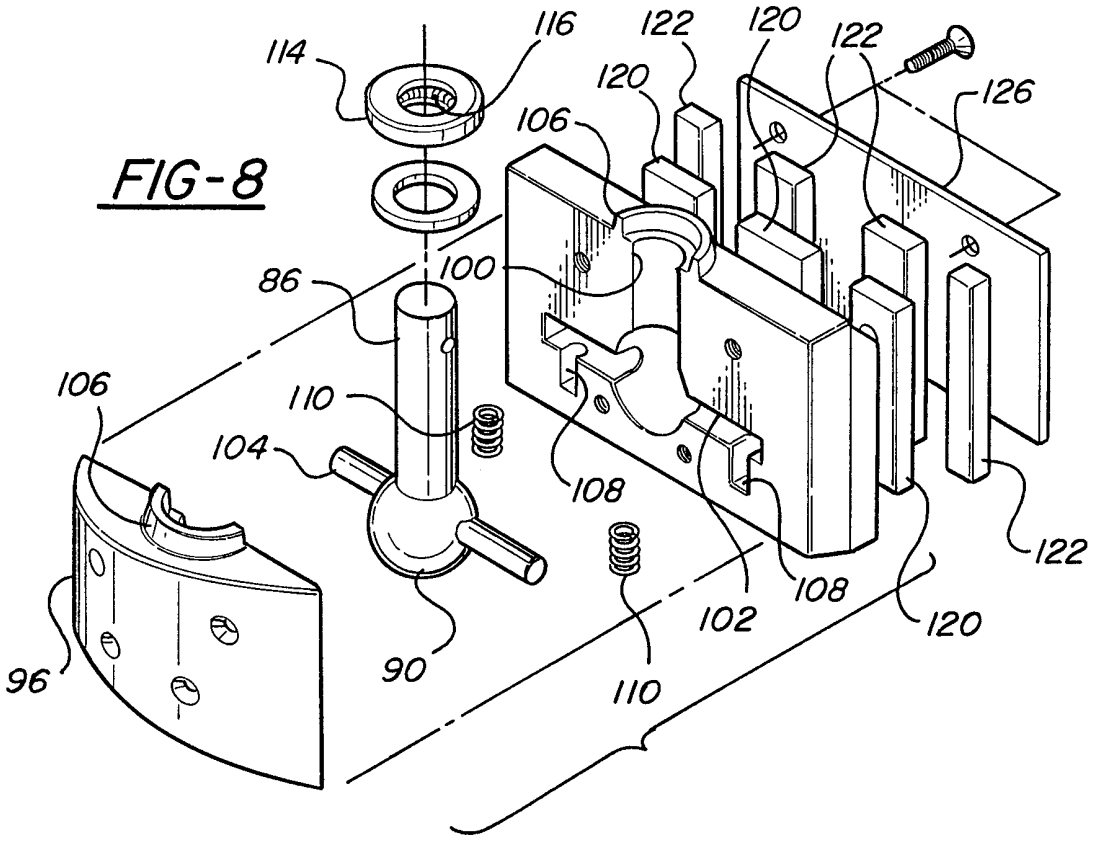
A5

FIG-8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96
90
110

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US98/22626

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :IPC (6) :B25J 15/06
US CL :Please See Extra Sheet.
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : U.S. : 414/733, 737
901/28,29,41,49: 335/289,286,295,306

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5,577,902 A (TODO ET AL) 26 NOVEMBER 1996 (26.11.96), FIG. 1	1,14,15,16, 17,18,20
Y	US 4,739,241 A (VACHTSEVANOS ET AL) 19 APRIL 1998 (19.04.88), FIG. 1	1,14,15,16, 17,18,20
Y	US 5,361,881 A (SIMOND) 08 NOVEMBER 1994 (08.11.94) COL.3, LINES 60-63.	14,15,16, 17
Y	US 5,062,855 A (RINCOE) 05 NOVEMBER 1991 (05.11.91), FIG. 4	18,20
Y	US 4,663,602 A (PIGNATARO) 05 MAY 1987 (05.05.87), FIG.3	18,20
Y	US 4,283,165 A (VERTUT) 11 AUGUST 1981 (11.08.81), FIG 1.	1,14,15,16,17,18, 20

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

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"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
18 DECEMBER 1998	14 JAN 1999
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-3230	Authorized officer D. Underwood Telephone No. (703) 308-1113

Form PCT/ISA/210 (second sheet)(July 1992)★

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US98/22626

A. CLASSIFICATION OF SUBJECT MATTER:
US CL :

U.S. : 414/733, 737
901/28,29,41,49: 335/289,286,295,306